Check List the journal of biodiversity data

NOTES ON GEOGRAPHIC DISTRIBUTION

Check List 18 (3): 575–581
https://doi.org/10.15560/18.3.575

PENSOFT

First record of *Caromiobenella helgolandica* (Claus, 1863) (Copepoda, Monstrilloida) from the Saudi waters of the Arabian Gulf

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Abstract

Caromiobenella helgolandica (Claus, 1863), a presumedly widespread monstrilloid copepod, is reported for the first time from Saudi waters of the Arabian Gulf; only females were found in zooplankton samples collected from Tarut Bay in the Arabian Gulf. *Caromiobenella* Jeon, Lee, & Soh, 2018 is a recently described genus that is distinguished by having modified male antennules. The nauplii of monstrilloid copepods are endoparasitic on molluscs and polychaetes, while the adults are free-living reproductive forms. This study is an unprecedented record of *C. helgolandica* from the Arabian Gulf region.

Keywords

Antennule, monospecificity, oral papilla, ovigerous spine, semi-parasitic

Academic editor: Jesser Fidelis de Souza Filho | Received 27 December 2021 | Accepted 15 May 2022 | Published 6 June 2022

Citation: Thomas B, Manikandan K, Qurban M, Clardy T, Sundaramanickam A, Suárez-Morales E (2022) First record of *Caromiobenella helgolandica* (Claus, 1863) (Copepoda, Monstrilloida) from the Saudi waters of the Arabian Gulf. Check List 18 (3): 575–581. https://doi.org/10.15560/18.3.575

Introduction

Monstrilloida is one of the least studied copepod orders. They have a peculiar parasitic life in which their larvae are endoparasites of molluscs and polychaetes, while the adults are non-feeding, free-swimming, and reproductive forms (Huys and Boxshall 1991; Huys et al. 2007; Suárez-Morales et al. 2010; Suárez-Morales 2011). There are currently seven valid genera in the single family Monstrillidae of the order Monstrilloida (Grygier and Ohtsuka 2008; Suárez-Morales and McKinnon 2014; Jeon et al. 2018; Suárez-Morales 2019; Suárez-Morales and Grygier 2021). One of the most recently described is *Caromiobenella* Jeon, Lee & Soh, 2018, which includes 10 species found in different geographic regions (da Cruz Lopes da Rosa et al. 2021). Jeon et al. (2018) found that species with modified male antennules (i.e., having a distinctive set of four or five distal spinule rows), differed both morphologically and genetically from most *Monstrilla* species and proposed the genus *Caromiobenella*

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to accommodate species possessing such modified male antennules. *Monstrilla helgolandica*, a widespread nominal species (Grygier 1995), was also assigned to this genus. The monospecificity of this species has been questioned because of several occurrences from widely disparate locations (Grygier and Ohtsuka 1995; Suárez-Morales 2011). Hence, comparative morphological data of monstrilloids from different regions represents a valuable resource to reveal their taxonomic status.

The monstrilloid copepod fauna is relatively unknown across vast geographic regions because of its rarity in the plankton and taxonomic complexity (Suárez-Morales 2011). One of the major challenges in discovering the real diversity of monstrilloid species has been matching the two sexes (Grygier and Ohtsuka 2008; Suárez-Morales 2011). Monstrilloids have been documented to show seasonal peaks of abundance in the water column and are found to be associated with water masses (Suárez-Morales 2011). There is still a paucity of knowledge concerning their seasonality and reproductive behavior.

The Arabian Gulf is a semi-enclosed sea. A counterclockwise movement of waters entering the Arabian Gulf through the Straits of Hormuz, from the Arabian Sea, is the predominant circulation pattern. However, there is no information on the impact of this circulation, as well as other currents, on the waters and organisms of the northwest Gulf (Michel and Herring 1984; Sheppard et al. 2010). In the Saudi Arabian Gulf, Tarut Bay is a shallow, sandy, and well-protected bay with extensive seagrass beds, coral patches, mangrove vegetation, and saltmarshes (El-Sorogy et al. 2016). Since the bay is less affected by wind and water currents, fine particles and organic waste discharge from the surrounding area settle, making it one of the nutrient-rich zones in the Saudi waters of the Gulf.

Caromiobenella helgolandica (Claus, 1863) is assumed to have a cosmopolitan distribution (Fig. 1A). It has been reported previously from North Sea (Claus 1863), Black Sea (Dolgopolyskaya 1948), Bay of Fundy (McMurrich 1917), Ungava Bay (Fontaine 1955), Norway (Sars 1921), Gulf of Maine (McAlice 1985), Ireland (Bailey 1963), English Channel (Isaac 1974), Bay of Biscay (Beraho et al. 2015), Mediterranean Sea (Suárez-Morales and Grygier 2021), Gilbert Island (McAlice 1985), Georgia Strait (Park 1967), West Tangier (Rose and Vaissèire 1952), Argentina (Dias and Bonecker 2007), Andaman Sea (Sewell 1949), Malaysia (Sewell 1949), South China Sea (Grygier 1995), and Indonesia (Scott 1909).

There are only a few records of monstrilloid copepods from the Arabian Gulf (Michel and Herring 1984; Ajeel 2017). Michel and Herring (1984) reported the monstrilloid copepod *Cymbasoma longispinosum* in Kuwaiti waters. This is the first time the species *Caromiobenella helgolandica* is documented from the western zone of the Indian Ocean. In this work, we record *C. helgolandica*, which was found in the Saudi waters of the Arabian Gulf.

Methods

Three intact, adult female specimens of *Caromiobenella helgolandica* were encountered during zooplankton analyses of the samples collected from the Tarut Bay (Fig.1B) in the Saudi waters of the Arabian Gulf (26°34′40.3″N, 050°07′16.7″E). Sampling was conducted in February 2019. Zooplankton samples were collected using a plankton net with a 0.3 mm mesh by horizontal tow for 10 minutes. A Folsom plankton splitter was used to divide the samples in half. Samples were fixed and preserved in 4% buffered formalin. The subsamples were sorted, and the specimens were mounted on a glass slide with a mixture of glycerin and distilled water in equal proportions for subsequent observations and measurements. The sampling details are given in Table 1.

Specimens were observed using an Olympus CX41 microscope. Digital photographs were taken using a Canon EOS 800D camera. An ocular micrometer was used to take measurements. Drawings were made using a drawing tube fitted to the microscope. The morphological description and terminology for female monstrilloids, proposed by Huys and Boxshall (1991) and Grygier and Ohtsuka (1995, 2008), were followed. Voucher specimens (TSA-272019) were deposited in the zooplankton collection of the Marine Section of King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia. Since the species does not fall under a protected category, no special permit was needed for the collection.

Results

Order Monstrilloida Sars, 1903
Family Monstrillidae Dana, 1849
Genus *Caromiobenella* Jeon, Lee & Soh, 2018

***Caromiobenella helgolandica* (Claus, 1863)**
Figures 2, 3; Table 2

New record. SAUDI ARABIA – **Eastern Province** • Tarut Bay; 26°34′40.3″N, 050°07′16.7″E; 10 m depth, average seawater temperature 17.1 °C; 21-II-2019; Todd Clardy leg. 0.3 mm mesh plankton net; KFUPM TSA-272019, 3♀, formalin. Males not collected.

Identification. Female *C. helgolandica* can be identified by the following characteristics: a robust body, with

Table 1. Details of zooplankton sample collection

Net mesh size (mm)	Date of sample collection	Time (Arabian standard time)	Towing duration (min)	Method of hauling	Method of subsampling	Condition of the specimens
0.3	27 Feb. 2019	0800	10	Horizontal	Folsom plankton splitter	Intact

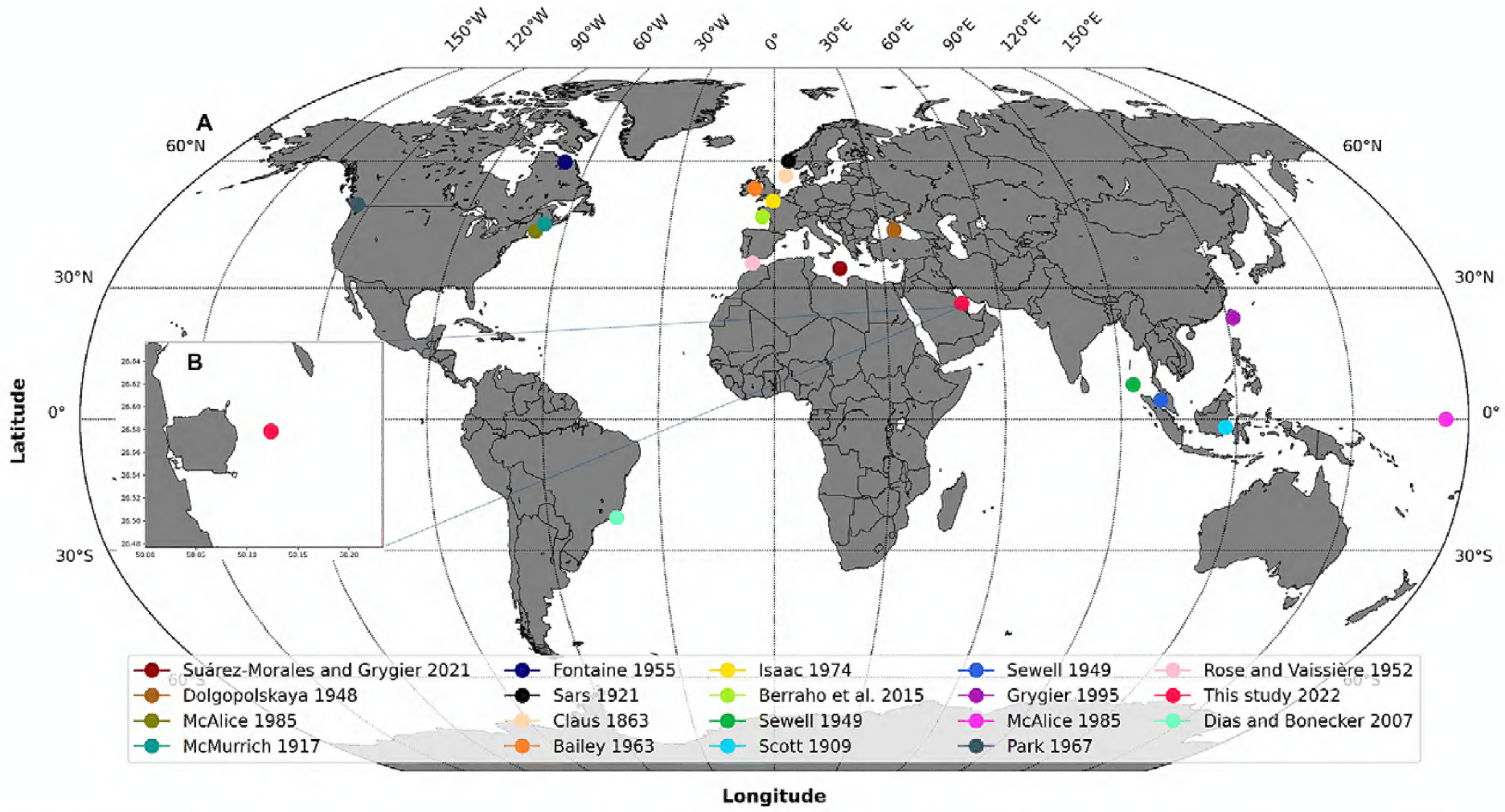

Figure 1. Global distribution of *Caromiobenella helgolandica*. **A**. Colored circles indicate previous and present records. **B**. Study site, with Tarut Bay magnified.

a light reddish-brown color for fresh specimens and a dark brownish color for formalin-preserved specimens; four-segmented antennules; a prominent oral papilla on the ventral side nearly in the middle; a slender and divergent fifth leg armed with two setae; a four-segmented urosome; a large genital somite; ovigerous spines of

Figure 2. *Caromiobenella helgolandica* female. **A.** Habitus lateral view. **B.** Cephalic region showing antennules and eyes. **C.** Urosome lateral view, showing fifth leg, genital double somite and ovigerous spines. **D.** Urosome ventral view showing fifth leg. **E**. Urosome dorsal view. Scale bars = 100 *µm*.

Table 2. Setae and Spine armature of legs 1–4.

	Basis	Exopod	Endopod
Leg 1	1-0	I-1:0-1: I,2,2	0-1:0-1:1,2,2
Legs 2-4	1-0	I-1:0-1: I,2,3	0-1:0-1:1,2,2

medium length; caudal rami with six setae each.

Description. Three female specimens were examined. The body is elongated and transparent anteriorly, with fine corrugations on the rest of the body (Fig. 2A). The total body lengths were 1.021 mm, 1.033 mm, and 1.058 mm (mean = 1.037 mm). The measurements were taken from the anterior end of the cephalothorax to the posterior margin of the anal somite, dorsally.

Robust cephalothorax (Fig. 2A), widest at the proximal one-third, measuring 0.521 mm, 0.527 mm, and 0.540 mm (mean = 0.529 mm), accounting for 51% of total body length. Eyes are represented by a medial cup and two smaller lateral ocelli (Fig. 1B). Conical oral papilla (Fig. 3A), at 47% of the way back along the ventral surface of the cephalothorax. The first pedigerous segment, which bears the first leg, is fused to the cephalic segment.

Antennules (Fig. 2B) are upright, 4-segmented, measuring 0.220 mm, 0.223 mm, and 0.231 mm respectively (mean = 0.225 mm), which is almost 42.5% of the cephalothorax length. Antennules are ornamented with spiniform setae, simple setae, plumose setae, and aesthetascs; none of the setae are branched. The first segment of the antennule has only one element, a spiniform seta. The second segment possesses six elements: five spiniform setae and one plumose seta. The third segment is armed with three elements: one spiniform seta and two plumose setae. Two aesthetascs, one at the proximal end and the other at the apex, nine spiniform setae, five plumose setae, and six simple setae, which are neither plumose nor branched, adorn the fourth or distal segment. Out of the six simple setae which are placed distally on the fourth segment, four are longer and thicker than the other two.

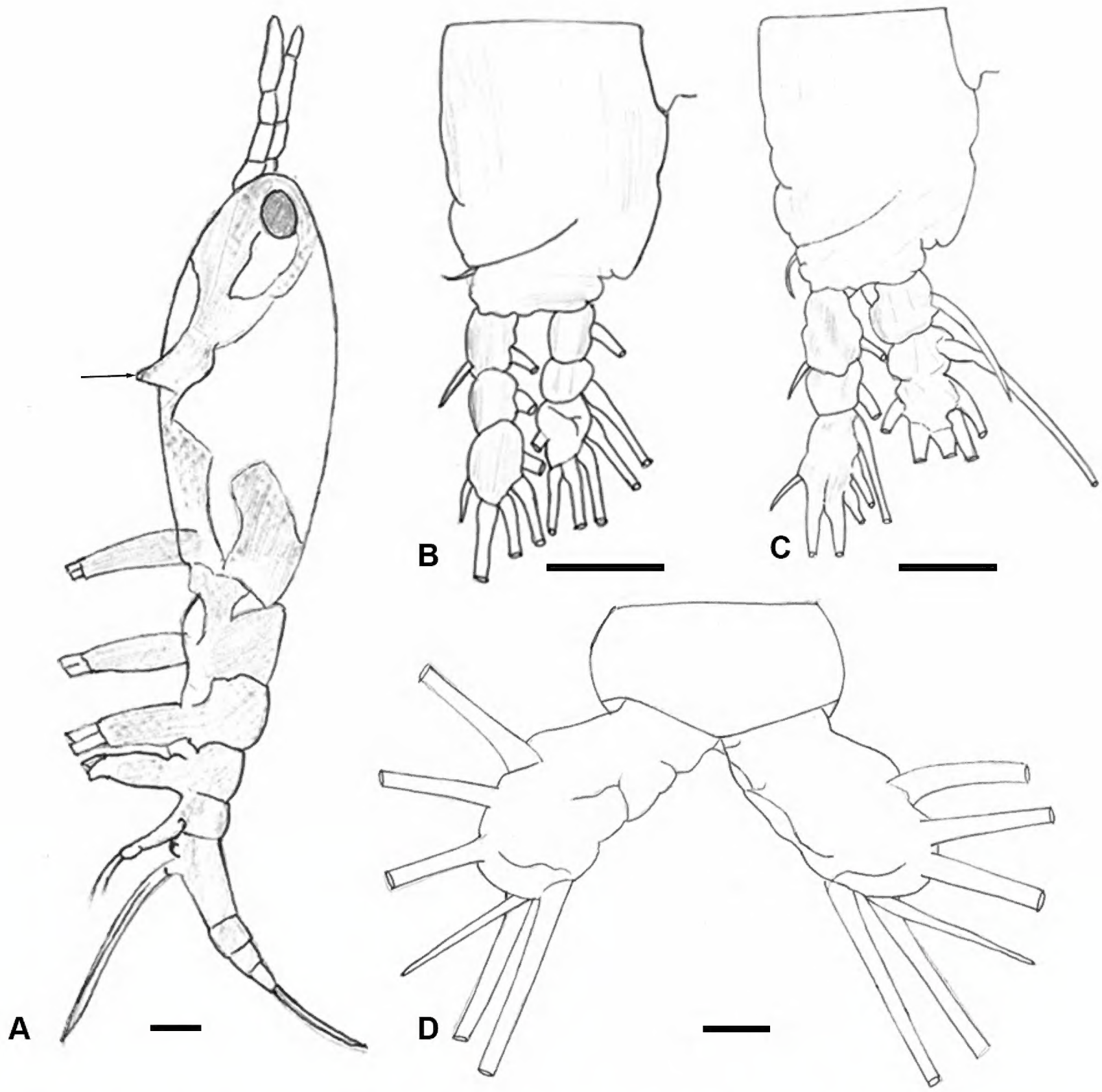

Figure 3. *Caromiobenella helgolandica* female. **A.** Habitus lateral view showing position of oral papilla; afully **B.** First leg. **C.** Second leg. **D.** Caudal rami dorsal view. **B–D.** Setae not fully drawn. Scale bars = 100 *μm*.

Metasome bears the rest of the legs 2–4. Swimming legs 1–4 biramous. Armament pattern of all the legs same, with only one difference in leg 1 (Fig. 3B, C), which has four setae on the third segment of the exopodite. Legs 2–4 have five setae on the exopodite segment 3. The setae are all plumose. Setae and spine armament formulas of the swimming legs 1–4 are given in Table 2: roman numerals denote spines, and arabic numerals denote setae.

Urosome (Fig. 2D) has four segments, including a fifth pedigerous segment, a genital double somite, a single succeeding free somite, and an anal somite. Fifth legs are distinct from legs 1–4 (Fig. 2C, D). They are slender, cylindrical, not straight, and have a bend nearly in the middle (Fig. 2C), apparent in the urosome's lateral view, and possess two subequal setae.

Genital double-somite (Fig. 2E): large, carries a pair of ovigerous spines that are joined and with attached egg mass. Ovigerous spines are longer than the caudal rami. In percentage terms, the length of the genital somite, subsequent free somite, and anal somite is roughly 65:21:14. The caudal rami diverge (Fig. 3D); they are oblong in shape and are almost as long as the last two urosomites combined. Each ramus has six unequally sized setae: one outer marginal seta and five apical setae, one of which is quite short and placed dorsally.

Remarks. Currently, there are 10 species that fall under the genus *Caromiobenella*. They are *C. pygmea* Suárez-Morales, 2000, *C. patagonica* Suárez-Morales, Ramírez & Derisio, 2008, *C. castorea* Jeon, Lee & Soh, 2018, *C. polluxea* Jeon, Lee & Soh, 2018, *C. arctica* Davis & Green, 1974 , *C. serricornis* Sars, 1921, *C. hamatapex* Grygier & Ohtsuka, 1995, *C. ohtsukai* Jeon, Lee & Soh, 2019, *C. helgolandica* Claus 1863, and *C. brasiliensis* Dias & Suárez-Morales, 2000 (Jeon et al. 2019; da Cruz Lopes da Rosa et al. 2021). Members of the genus *Caromiobenella* can be divided into two subgroups, one based on male genitalia and the other based on the display of five or six caudal setae (Jeon et al. 2019). *Caromiobenella castorea*, having six setae, and *C. polluxea*, with only five setae, are two subgroups based on caudal setae (Jeon et al. 2019). *Caromiobenella helgolandica*, *C. arctica*, *C. hamatapex*, *C. patagonica*, *C. ohtsukai*, and *C. brasiliensis* are members of the *C. castorea* species group. In this, only three species have their females documented: *C. hamatapex*, *C. helgolandica*, and *C. brasiliensis*. In *C. hamatapex*, one very prominent feature is that the ovigerous spines extend beyond the ends of the caudal setae. The newest member of the genus (da Cruz Lopes da Rosa et al. 2021), *Caromiobenella brasiliensis* Dias & Suárez-Morales, 2000, exhibits a wrinkled protuberance on the third segment of antennules and bilobed fifth legs with three setae in one lobe and one seta in the other. The genus *Maemonstrilla*, which belongs to the family Monstrillidae, has six setae on the caudal ramus as well, but it has an oral papilla much more anterior on the cephalothorax and anteriorly pointed ovigerous spines (Grygier and Ohtsuka 1995). Some species belonging to the genus *Monstrilla* have six caudal setae (Isaac 1975; Chang 2014), but there are differences in the position of the oral papilla, the structure of the fifth leg, the length of the ovigerous spines, and other characteristics.

Discussion

This study is the first distributional record of *Caromiobenella helgolandica* from the Arabian Gulf. The species was first reported from the Helgoland region of the North Sea by Claus (1863) and was named *Monstrilla helgolandica*. The specimens collected from the Arabian Gulf have the diagnostic features of female *M. helgolandica* as briefly described by Claus (1863), such as elongated body, brownish-red pigmentation, short antennules, and long genital segment, and by Sars (1921), such as a fusiform cephalic segment, four segmented antennules, eyes with three lenses, position of the oral papilla on the cephalothorax, structure of the fifth leg which is bent in the middle, ovigerous spines, and an oblong caudal ramus with six setae. Jeon et al. (2018) established the genus *Caromiobenella* because the males of the genus exhibit modified antennules.

Many authors have examined and reviewed *Monstrilla helgolandica* (Park 1967; Ramírez 1971; McAlice 1985; Huys and Boxshall 1991; Grygier and Ohtsuka 1995; Suarez Morales 2011). According to Park (1967), the species has a mean body length of 2.31 mm and antennules with only two distinct segments. The species has fine bristles on the first and second segments of both exopodites and endopodites of the legs, according to Ramírez (1971). However, Ramírez's species was later temporarily reclassified as *M. patagonica* (Suárez-Morales et al. 2008). Females with a mean length of 1.4 mm, just two distinct antennular segments, and fine setules on the fifth leg were described by McAlice (1985), which differs from the present specimens. Six caudal setae are found in *C. helgolandica* sensu McAlice (1985), but only five are found in *C. helgolandica* sensu Huys and Boxshall (1991). According to Grygier and Ohtsuka (1995), the ovigerous spines barely extend beyond the telson. Suárez-Morales (2011) concisely commented on the morphological discrepancies amongst the earlier recorded *Monstrilla helgolandica* specimens.

Even though the Arabian Gulf has a substantial human influence (Sheppard et al. 2010) due to oil exploration, drilling, transportation, and other activities, it offers ideal coastal habitats, such as fishing grounds and coral regions, for semiparasitic monstrilloid copepods to survive. Because *C. helgolandica* collected from different geographical regions varies in morphological characteristics and size, the taxonomy must be validated using modern molecular techniques. Considering the uniqueness of the monstrilloid copepods, extensive sampling throughout the year is required in order to fully comprehend the diversity and seasonality of the group in the region.

Acknowledgements

We express our gratitude to all the reviewers who have given their valuable suggestions to improve the content of this paper. No funding was needed for this work.

Authors' Contributions

Conceptualization: BT. Formal analysis: KM. Resources: TC. Supervision: MQ. Validation: AS. Writing – original draft: BT. Writing – review and editing: ESM.

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